Standard-based Data and Service Interoperability in eHealth Systems

Kamran Sartipi and Mohammad H. Yarmand
Department of Computing and Software
McMaster University
Hamilton, ON, L8S 4K1, Canada
{*sartipi, yarmanmh*}*@mcmaster.ca*

Abstract

International standardization in information representation, organization, and dissemination are meant to eliminate the discrepancies in communication among participating organizations and institutions in a particular domain. The management of domain information will then allow different participants to integrate their legacy information or application servers to a nation-wide network and use widely approved services to communicate their proprietary data and services with a large group of clients. In this context, traditional healthcare information systems require fundamental re-engineering to new network-centric environments in order to reduce the huge costs of healthcare while maintaining the expected quality of public health. This integration using new HL7 v3 standards and leading-edge information technologies will be the initial steps for shifting towards an interoperable healthcare environment. This paper aims at addressing new challenges in standard-based interoperability provision among legacy healthcare information systems, while adhering to international and national standards for data and service representations. We introduce a framework to employ healthcare standards and clinical terminology systems to achieve semantic interoperability between distributed Electronic Medical Record (EMR) systems. A real world case study for integration of a Clinical Decision Support System (CDSS) with the EMR of a specialist will be presented.

KEYWORDS: Legacy System; Migration; Interoperability; Healthcare; HL7; Standardization; Web Services.

1. Introduction

Emerging new software technologies and standards in distributed systems necessitates integration of existing legacy software systems with new network-centric architectures. In this context, provision of interoperability among systems to organize and exchange corporate information and application services would be of prime importance. This migration to new architecture requires data and service reverse engineering to understand the structure and organization of the information system, comprehending the available standards for data and services representations, and performing the actual mapping.

To tackle the complexity of network-centric interoperability, the trend is towards ease of use, vendor / language / platform independency, and in general raising the level of communication abstraction. The available technologies range from lower-level techniques such as RPC / RMI, to proprietary technologies such as CORBA / DCOM, to provider-independent techniques based on XML / web-services, to high-level of abstraction such as service oriented architecture (SOA). These technologies to a large extent have solved the problem of interoperability of heterogeneous distributed systems. However, yet another challenging issue to be tackled is the interoperability of terms and concepts between different information organizations, namely semantic interoperability. This necessitates a different type of communication abstraction which reduces the task of users from making frequent agreements on different concepts and services they use locally. This issue can be resolved through standard ontology systems and services for exchanging specialized applications and workflows.

Due to sensitivity of information in healthcare systems (mostly patient data) and a huge collection of terms and concepts, achieving interoperability among healthcare systems faces problems beyond those in most domains. Moreover, the growing cost of healthcare in most civilized countries has been the driving force to put a lot of efforts in this domain for defining standardization processes. These have resulted in developing international standards in common terminology systems (e.g., SNOMED and LOINC) and in organizing and representing the whole body of domain information into class diagrams (i.e., HL7 RIM). Therefore, any new attempt for interoperability among legacy healthcare systems should conform with these standards to ensure its compatibility and maintainability in the future. However, since these standards are rather new and have not been fully stabilized, only a few real-world standards-based interoperability projects have been attempted.

In this paper, we tackle this interoperability problem using international and national standards (HL7 and Canada Health Infoway) and provide guidelines and steps for using different documents to achieve standard data and service interoperability among legacy systems. A major part of this process requires understanding of the legacy system's data and services and also to which standard service and terms they can be mapped. This opens a new avenue for researchers in the reverse engineering community to develop processes and workflows to handle the problems of migration to new platforms and re-engineering of legacy systems in the context of standard concepts and operations.

The remaining of the paper is structured as follows. Section 2 describes the related work. Section 3 presents a brief background on healthcare standards that is used in the remaining of the paper. We explain our data and service interoperability framework in Section 4 and provide more details on data integration steps in Section 5. Section 6 introduces the case study environment and supplies some examples. In section 7 we mention the architecture for the case study and explain how to adopt a commercially available healthcare application development tool. Finally in Section 8 we conclude the paper together with a discussion.

2. Related work

The work in this paper is related to the following approaches in the related literature.

Souder and Mancoridis [27] propose a technique that covers the services of legacy systems by multiple wrappers to convert them into secure and distributed objects. These wrappers provide a virtual environment, known as a sandbox that is used to make components independent of the environment. A client/server approach for using the wrappers is also proposed that employs Java and CORBA technologies.

In the context of web service interoperability, Zou and Kontogiannis [30] propose an approach to identify reusable logic in legacy systems and their interaction with other systems, using reverse engineering techniques. This logic is embedded in CORBA wrappers and communicated by SOAP protocol to obtain interoperability. Once the services are distributable, it is necessary to let the service providers publish and advertise their services and let the clients search and locate those services.

Jin and Winter [23] discuss the data and service interoperability problem between reengineering tools. They mention Graph Xchange Language (GXL) as a mechanism for exchanging graph-based data to obtain data interoperability. For service interoperability they mention a service sharing methodology which uses domain ontology and conceptual service adaptors to interconnect these tools [22]. Once the participant tools satisfy certain requirements (such as storing fact instances), the tools are assigned to relevant ontology and the service adaptors extract and filter software facts, which addresses the syntactic aspect of integration process. The domain ontology stores representation and service concepts that are shared among participating tools in an integration, which also takes care of semantic interoperability. A service offered by a tool can be shared only when the concepts required by the service intersect with the concepts supported by another tool.

In the domain of healthcare, most of recent integration projects intend to use healthcare standards to obtain semantic interoperability. These projects scale from integration of a hospital subsystems to proposing general framework communication in distributed environments [29, 8, 24, 11, 9, 28]. However the architectures and configuration of proposed models vary from project to project. We use the architecture proposed by healthcare standardization organizations to produce reusable products. To the best of our knowledge, a few projects deal with usage of clinical terminologies in HL7 or Infoway.

3. Healthcare standards

The healthcare industry has many organizations developing specifications and standards to support healthcare informatics, information exchange, systems integration, and a wide spectrum of healthcare applications. International and nation-wide standards should be well understood and adopted appropriately to effectively integrate healthcare systems. In the following, two major international and national standard organizations that we adopted in our interoperability project will be discussed briefly.

3.1. HL7

HL7 is an international community of healthcare experts and information scientists collaborating to create standards for the exchange, management and integration of electronic healthcare information [5]. HL7 version 3 (HL7 v3) uses Reference Information Model (RIM), an object model that is a large class diagram representation of the clinical data and identifies the life cycle of events that a message will carry, and applies object-oriented development methodology on RIM and its extensions to create messages. In the following, two HL7 concepts, i.e., *message structure* and *refinement process* are briefly discussed; these concepts are the basis of our translation process [4, 10].

Message structure. At the highest level, an HL7 version 3 message is composed of two parts:

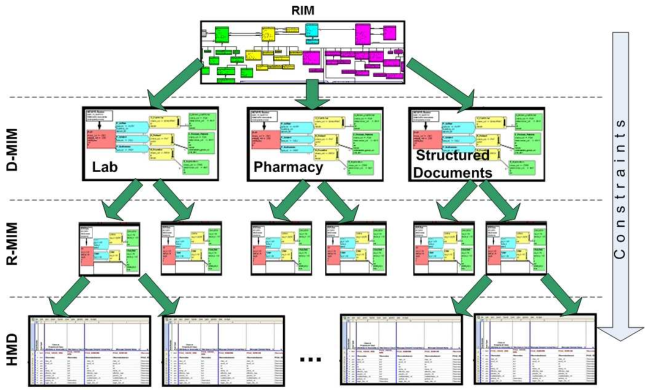

Figure 1. HL7 v3 information refinement process

- *HL7 Transmission Wrapper,* includes information needed by a sending application or message handling service to package and route the v3 messages to the designated receiving applications or message handling services.

- *HL7 Transmission Content*, contains core data attributes for the message such as a prescription order or dispense event. It also includes information about the business event that initiated the sending of this message, who sent it and other associated business information.

Refinement process. HL7 methodology uses RIM, HL7-specified Vocabulary Domains, and version 3 Data Type Specification as its starting point. It then establishes the rules for refining these base standards to arrive at the information structures that specify Message Types and equivalent structures in v3.

The strategy for development of version 3 messages and related information structures is based upon the consistent application of constraints to a pair of base specifications, i.e., HL7 RIM and HL7 Vocabulary Domains, and upon the extension of those specifications to create representations constrained to address a specific healthcare requirement. Figure 1 shows the refinement process specified in HL7 methodology, where the different parts are discussed below.

- *Domain Message Information Model* (D-MIM) is a subset of the RIM that includes a fully expanded set of class clones, attributes and relationships that are used to create messages for any particular domain.

- *Refined Message Information Model* (R-MIM) is used to express the information content for one or more messages within a domain. Each R-MIM is a subset of the D-MIM and contains only those classes, attributes and associations required to compose the set of messages.

- *Hierarchical Message Description* (HMD) is a tabular representation of the sequence of elements (i.e., classes, attributes and associations) represented in an R-MIM. Each HMD produces a single base message template from which the specific message types are drawn.

- *Message Type* represents a unique set of constraints that are presented in both grid and table view as well as an Excel spreadsheet.

3.2. Canada Health Infoway

Infoway [1] is an organization that provides specifications for a standard and nationwide healthcare infrastructure. Infoway's mission is to foster and accelerate the development and adoption of an interoperable Electronic Health Record (EHR) system which is compatible with HL7 standards and communications technologies. The EHR system would include information relating to the current and historical health, medical conditions and medical tests of the Canada's population and is typically accessed on a computer or over a network. In order to achieve this goal, Infoway has suggested a refinement for an Electronic Health Record Solution called EHR Infostructure (EHRi). The Infoway's Infostructure is illustrated as the *standard-based interoperability system* in Figure 2. Infoway's *Health Information Access Layer* (HIAL) provides standardized common services and communication services to sustain the interoperability of the different components within the infostructure, as well as to sustain interoperability and a high degree of abstraction between the EHR infostructure and the point of service applications. Communication bus services are divided into messaging (including transformation, routing, encrypt/decrypt, encode/decode, parser and serialization) and protocol (including applications protocol and network protocol).

Clinical terminologies. A clinical terminology system facilitates identifying and accessing information pertaining to the healthcare process and hence improves the provision of healthcare services by the care providers. A clinical terminology system can allow a healthcare provider to identify patients based on certain coded information in their records, and thereby facilitate follow-up and treatment. A major clinical terminology that is used in our project will be explained below.

SNOMED Clinical Terms (SNOMED CT) is a comprehensive clinical terminology system that provides clinical content and expressiveness for clinical documentation and reporting. It can be used to code, retrieve, and analyze clinical data. The terminology is comprised of concepts, terms and relationships with the objective of precisely representing clinical information across the scope of healthcare. SNOMED CT uses healthcare software applications that focus on collection of clinical data, linking to clinical knowledge bases, information retrieval, as well as data aggregation and exchange [26].

4. Proposed framework

Figure 2 illustrates the proposed framework for standard-based data and service interoperability, where two legacy healthcare systems (left) are migrated into HL7-based Canada Health Infoway's standard architecture. According to a typical reverse engineering task, the software engineers investigate available information sources such as: healthcare domain knowledge (HL7), system's technical and user manuals, and knowledge of an expert, to extract a set of relevant task scenarios as well as data schemas that are used in the interactions. Different parts of Figure 2 are described below.

Existing systems. Most existing legacy healthcare systems communicate their data and results of services through fax machines, telephone calls, and regular mailing system, which are costly, slow, non-reliable, hard to maintain, and cause redundancies in filing information. The goal is to replace traditional communication techniques with state-of-the-art standard-based interoperable systems shown in Figure 2 (right)

Interoperability process. This part represents the steps required to migrate the data and services of the legacy systems into standard-based and interoperable systems.

The rectangles inside the large box represent different artifacts that will be generated during the process, and rounded-boxes on top, represent standard documentations that are available from standard organizations HL7 [5], Canada Health Infoway [1], and SNOMED [7, 6]. In order to map legacy services into Infoway standard, the following concepts are defined.

Storyboard is a short story used to define the business requirements via a narrative of relevant events defined using interaction diagrams or use cases.

Transaction is a single use-case within the interaction diagram that represents a particular functionality of the system that is performed by interacting with the system. A storyboard can generate several transactions.

Interaction is a single, one-way information flow that supports a communication requirement expressed in a scenario.

Trigger event is a UML term for an event, where an application uses an event to initiate an interaction in order to transfer information to another application.

Application role represents the responsibility of an application during the interaction with another application that is initiated by a trigger-event.

The rest of boxes are used for data refinement process of the HL7 standard and are defined in subsection 3.1.

Standard-based interoperating system. This part represents the integration of the transformed messages of the legacy system (as *HL7 standard messages*) with the Infoway's Infostructure which takes advantage of standard services of the Infoway architecture and communication using service oriented architecture and many other standard services, as specified by the Infoway's EHRi blueprint [12]. In the new interoperable environment, the legacy healthcare systems use HL7 message structure discussed in section 3.1 to exchange their data and services.

In the following section, the details of the data interoperability process is described, where the resulting XML formatted data will be fed to the HL7 standard messages that are specified by the *interoperability process* of Figure 2.

5. Data interoperability

In order to obtain semantic interoperability between healthcare applications, their clinical terms should be mapped to unique terminology systems. In this project we map the data fields of two healthcare systems onto the HL7 v3 clinical terms that are specified by Infoway. In order to map a system data schema to Infoway's standard, first we should determine to which project of the Infoway infostructure this data schema belongs to. In our case study, Infoway projects *iEHR*, *CeRx*, *Lab*, *Client Registry*, and *Provider Registry* are used. For each of the above projects three documents are used for the mapping process.

- **Vocabulary Status Worksheet** [15, 13]. This document has been designed to provide a logically complete explanation of the set of terminology codes required by the Message Specification. It is arranged in such a way that a series of cross links exist to take the reader to a particular domain to describe the set of terminology codes that have been recommended for that domain.

- **Message Definition Worksheet** [20]. This document is used for high level mapping between a system's data fields and major clinical concept groups (e.g., Professional Service, Clinical Observation).

- **Scope & Package Tracking Framework** [21]. For some of the above mentioned projects "Message Definition Worksheet" document has not been created. In such cases, "Scope & Package Tracking Framework"

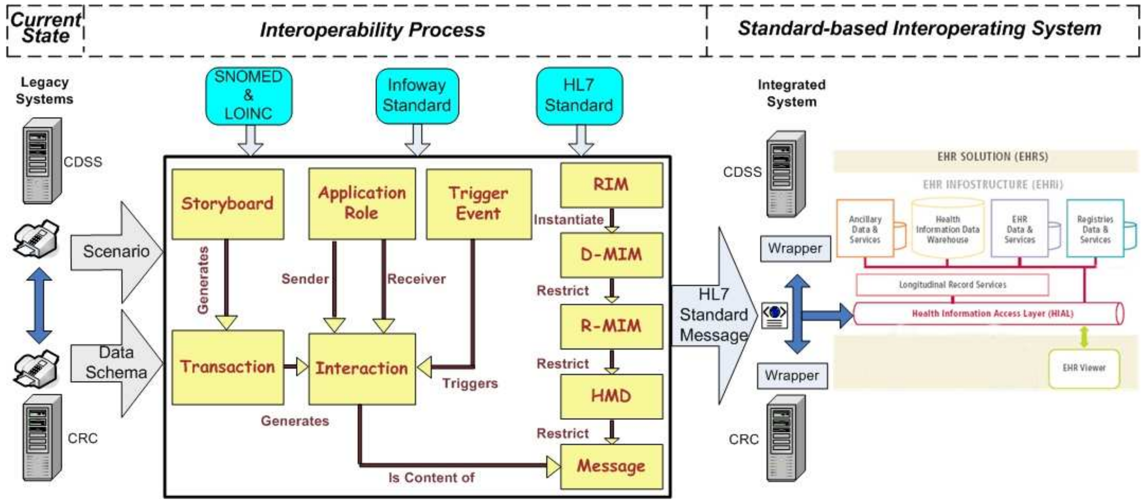

Figure 2. Proposed standard-based framework for data and service interoperability in eHealth systems.

is used to retrieve relevant Transactions. Each Transaction is composed of one or more Interactions. For each Interaction appropriate Message Model document is defined which expresses the R-MIM fields.

Each *concept* within HL7 RIM is bound to two terms, that are: "labeling" which refers to a concept's attribute; and "value" which refers to the attribute's value. Generally a LOINC [6] term is used as a label and a SNOMED term is used as a value. For example for the height of a patient, Infoway selects *'body height - measured'* with code 3137-7 from LOINC as a label and 'Body height measure (observable entity)' with code 50373000 from SNOMED as a value. Both in SNOMED and LOINC, a unique concept with a unique code might be found under different branches of the SNOMED/LOINC's concept tree. In this case the judgement of an expert is required to decide on the most relevant concept to the local term. In the following and using Figure 3, we will explain in more details the steps required to generate HL7 v3 messages according to Infoway standard.

The overall translation model consists of: *legacy healthcare system* (left); *data and service interoperability process* (middle); and HL7 / Infoway *documentations* (surrounding boxes) for generating HL7 v3 standard messages from typical healthcare scenarios. The legacy healthcare system supplies healthcare scenarios and receives the HL7 v3 messages that implement those scenarios. This is done through a proposed set of steps that are organized into three phases: *Interaction Extraction*, *Message Selection*, and *Domain Analysis*. Finally, the interoperability process uses HL7 and Infoway standard documents in different steps. The three phases are describe below in more details.

Phase 1: Interaction Extraction.
In this phase, HL7 standard interactions are identified through analysis of transactions. Given a scenario of legacy healthcare system, we divide it to smaller transactions required to complete a scenario. By reviewing the list of transactions of "Scope & Package Tracking Framework" document, the legacy transactions are mapped to the standard transactions which have similar semantics. Each transaction consists of a set of interactions to support *outbound* and *inbound* communications (i.e. send/receive pairs). Detailed explanation about usage and rational of each transaction is explained in Implementation Guides of the projects [17, 18, 19])

Phase 2: Message Selection.
In this phase, the elements of HL7 message structure (i.e., Transmission Wrapper, Trigger Event Control Act Wrapper and Message Payload) are created. Each interaction resulted form previous phase is assigned to a transmission wrapper schema. The transmission content is defined in this schema. Transmission content is represented in Word, Excel, XSD and MIF formats [16, 14]. The semantic of transaction content can be understood from the associated R-MIM.

Phase 3: Domain Analysis.
In this phase, the final HL7 v3 message instance is generated from the message schema resulted form last phase. The HL7 domain that should be used for each field of schema

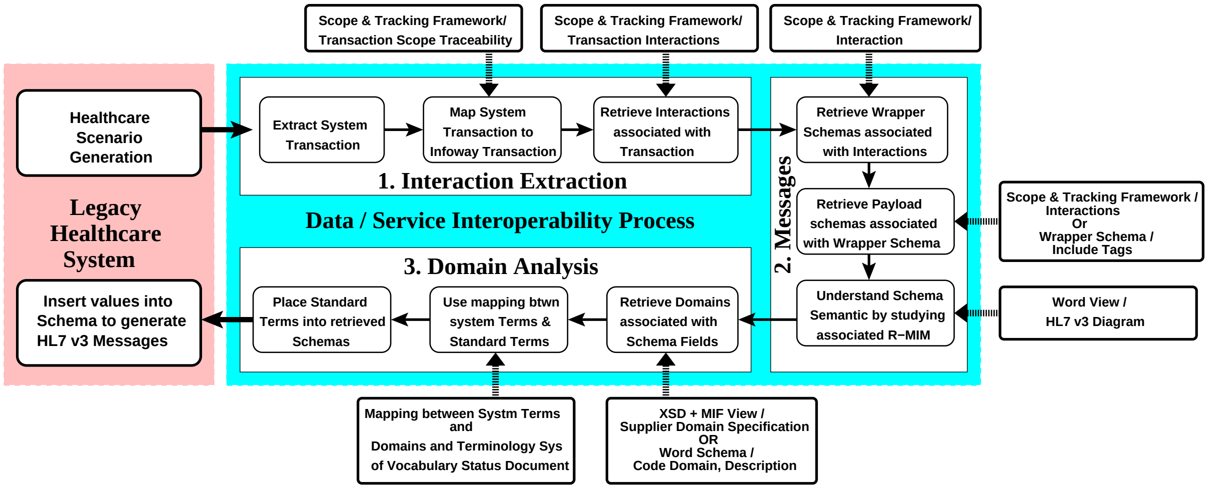

Figure 3. The proposed model for translating healthcare scenarios to standard HL7 v3 messages.

(and the rational behind this choice) is mentioned inside the schema. The clinical terminology system that should be used for each HL7 domain is defined in 'Vocabulary Status' document.

Parallel to the steps explained in these phases, a mapping file should be generated that assigns data fields of legacy system to HL7 domains and the appropriate clinical terminology system concept defined by HL7. A clinical expert should assist the process of creation of this mapping file. Using this mapping file and domains of HL7 schema extracted in the last step, another mapping file should be generated to map legacy system data fields to HL7 domain, HL7 message and the appropriate filed inside the message schema. Using this second mapping file, the pair <*legacy attribute*, *value*> can be translated by <*HL7 attribute mapped to legacy attribute*, *value*> inside the HL7 message XML.

6. Case study environment

We are involved in a project with collaboration of an industrial partner and two medical research groups to integrate a decision support system with a specialist application. This is one of the pioneer projects in integrating healthcare system which is compliant with new HL7 v3 and Infoway standards and employs the leading edge information technology in this field. The steps proposed in the last section are applied and evaluated in this real-world project.

COMPETE III Vascular Tracker (C3VT) is a decision support system that assists physicians to observe and ideally control patients' different risk factors within the domains of cardiovascular, diabetes, hypertension, and dyslipidemia diseases. C3VT's database contains a large body of knowledge gathered by rigorous study of the related literature in compliance with the internationally accepted methodology known as "evidence-based practice". The clinical algorithms have been so fine-tuned that cover different cases of most individual patients. COMPETE III study has been built up on the long-term experiences gained through COMPETE I & II studies and have reached to a point that is confidently used by a large group of physicians [2].

As a further step in COMPETE III project, the research group would like to extend the scope by providing its services to other research group specialized applications through nation-wide standard specifications proposed by Canada Health Infoway. The expansion of the C3VT capabilities will take place within a pilot project that will allow C3VT to interoperate with a Cardiac Rehab Center (CRC) in a different city. In this integration a portion of patient data form CRC is sent to C3VT, such that the C3VT algorithms can be run on these data and corresponding recommendations and guidelines are returned to CRC.

CRC accepts patients who have had heart surgery or vascular operation and monitors their clinical status for a period of six months. Each year nearly 400 new patients are accepted to the center. This rehabilitation program is running in other places and the total number of patients exceeds 8000 patients. The employed information system in the center offers extensive capabilities to enter different critical clinical data for each patient and track their health situations.

6.1. Project steps

The project is progressing well and different use cases and scenarios of the integrated system have been extracted and modeled. The set of Infoway transactions which are required to perform the scenario are selected. The set of additional information to be transferred with each clinical

COMPETE III VT	SNOMED Candidates	Concept Code
Flu shot	Procedure/ Procedure by method/ Introduction/ Administration of therapeutic substance/ Immunization/ Active immunization/ Viral immunization/ Influenza vaccination	86198006

(a)

COMPETE III VT	HL7 Message Model	Message field	HL7 Domain	Infoway Candidates	Code	Terminology	Owning Project
Flu shot	REPC_MT610001CA - Professional Service Procedure Record	Professional Service/ Service Type	ActProfessionalServiceCode	Influenza vaccination	86198006	SNOMED	iEHR

(b)

Figure 4. (a) Mapping C3VT data schema to SNOMED. (b) Mapping C3VT to Healthcare Standards.

Scenario	Transaction	Interaction	Trigger	Application Role	Application Role
Immunization	Add Patient imm.	Record imm. request	Request to record imm.	Imm. Entry Sys.	Imm. Repository
		Record imm. request accepted	Imm. recorded	Imm. Entry Sys.	Imm. Repository
		Record imm. request refused	Decision to not record imm.	Imm. Entry Sys.	Imm. Repository
	Patient imm. Query	Imms. query	Patient imm. information requested	Imm. Repository	imm. Querying Sys.
		Imms. query response	Request for patient notes received	Imm. Repository	imm. Querying Sys.
	Update Patient imm.	Update imm. request	Request to revise imm.	Imm. Entry Sys.	Imm. Repository
		Update imm. request accepted	Imm. revised	Imm. Entry Sys.	Imm. Repository
		Update imm. request refused	Decision to not revise imm.	Imm. Entry Sys.	Imm. Repository
	Retract imm. Record	Retract imm. request	Imm. reversal has been requested	Imm. Entry Sys.	Imm. Repository
		Retract imm. request accepted	Imm. has been reversed	Imm. Entry Sys.	Imm. Repository
		Retract imm. request refused	Imm. reversal has been refused	Imm. Entry Sys.	Imm. Repository

Figure 5. Mapping legacy system services to Canada Health Infoway services

concept such as dates, requester and performer are defined for high levels of data schema (such as vital signs, procedure and lab).

In the next step, the data schema of the two systems have been mapped to the standard format. In our project, this process resulted in four mapping files for SNOEMD, LOINC, Infoway and HL7 which are finalized in an integrated extended version. The C3VT's responses (i.e., recommendations and guides) are expressed using HL7 suggestion for CDSS expression which are in turn expressed in GELLO language [3]. In a clinical context, GELLO can interact with any HL7 RIM-based object oriented data model serving as intermediary to heterogeneous medical record systems.

Once these data schemas are mapped to HL7 standards, a framework is set up to transmit these data between two systems which completes the semantic interoperability. A modern tool developed specially for healthcare purposes is used to build this environment which is explained in the next section. The environment creates the different elements of the Infoway infostructure to provide the required functionality. The mapping process is embedded into Infoway's HAIL message bus. The whole environment for this data and service integration project will serve us as a vehicle to apply our future research ideas in the healthcare domain. Currently we have developed a new general and customizable security and privacy technique to provide confidentiality and reliability of context-aware access control.

6.2. Data & Service mapping process

In order to facilitate the mapping process, initially the C3VT data schema is completely mapped onto the SNOMED CT. Figure 4(a) presents a sample mapping. By this mapping, the time required to trim irrelevant clinical terminology branches based on domain selection is reduced dramatically. Also the knowledge gained about SNOMED hierarchy through this mapping data schema to SNOMED is necessary to select the relevant domain from standard documents.

The outcome of data mapping process is a mapping be-

Integrated System Service	Transaction ID	Transaction Name
Load Patient Profile	C21.10	Get Patient Clinical Observation Document
	C13.02	List Patient Professional Services
	C27.02	List Patient Care Composition Summaries
	C29.04	List Patient Referral Summaries
	C12.03	List Patient Health Condition Summaries
Update Patient Profile	C21.08	Record Patient Clinical Observation Document
	C13.01	Record Patient Professional Service
	C27.01	Record Patient Care Composition
	C29.01	Record Patient Referral
	C12.01	Record Patient Health Condition

Figure 6. Mapping system services to HL7 standard transactions.

tween legacy system data schema; HL7 messages; clinical domain; clinical terminology system hierarchy; and finally the extracted standard code for legacy data. Figure 4(b) presents a sample of mapping for the C3VT system. In this sample, the "*Flu shot*" field from C3VT is mapped onto the "*ActProfessionalServiceCode*" domain and the appropriate message and the specific field of the message is identified.

The complete service mapping is performed in two steps.

- **First mapping** occurs among the standard documents. For example, in order to transfer the *flu-shot* information of a patient, we need to use the immunization storyboard. The first mapping, as shown in Figure 5, should find the proper transaction; interactions; trigger events and application roles, that are associated with the immunization storyboard. The mapping is performed by navigating the "Scope & Package Tracking Framework" document.

- **Second mapping** is dedicated to selecting standard transactions that are required to perform a transaction of the legacy system. In our case study, two transactions are responsible for recording and retrieving the medical record of a patient. Considering the sections defined for a patient profile in our system (such as clinical observations and clinical procedures) we select the appropriate transactions to transfer these data. An example is shown in Figure 6.

A portion of the output of data mapping process, i.e., HL7 v3 message for transferring flu-shot data, is shown in figure 7. The "Service Type" of the "Professional Service Procedure Record" message is the selected field to transfer flu-shot data. The SNOMED code is selected from Figure 4(a) and the domain of "Service Type" field is compliant with Figure 4(b). The message also contains additional information such as the performer of the procedure, the reason for procedure request, the person who should be notified of procedure completion, etc.


```
<ProcedureEvent moodCode="EVN" classCode="PROC">
  <ServiceType code="86198006" codeSystem="2.16.840.1.113883.6.96"
    codeSystemName="SNOMED-CT" displayName="Influenza Vaccination" />
  <statusCode code="completed" />
  <effectiveTime value="20071122" />
  <confidentialitycode code="N" codeSystem="2.16.840.1.113883.5.25"
    codeSystemName="HL7 Confidentiality" displayName="Normal" />
  <Performer />
  <informant />
+ <location typeCode="LOC" contextControlCode="OP">
- <infulfillmentOf typeCode="FLFS" contextControlCode="ON" contextConductionInd="true"
  - <observationRequest moodCode="RQO" classCode="required">
      <id value="a referral or record id" />
    - <author2 typeCode="AUT" contextControlCode="OP">
      - <assignedEntiry1 classCode="ASSIGNED">
          <id />
          <code typeCode="" codeSystem=""
            codeSystemName="HealthcareProviderRoleType"
            displayName="physician" />
          <telecom />
          <assignedPerson />
        - <representedOrganization classCode="ORG" determinerCode="INSTANCE">
            <id />
            <name value="COMPETE" />
          + <assignedOrganization classCode="ASSIGNED">
          </representedOrganization>
        </assignedEntiry1>
      </author2>
    </observationRequest>
  </infulfillmentOf>
  <definition />
  <predecessor />
- <reason typeCode="RSON" contextControlCode="AN" contextConductionInd="true">
  + <observationCondition moodCode="EVN" classCode="OBS">
  + <otherIndication moodCode="EVN" classCode="ACT">
  </reason>
  <subjectOf1 />
  <subjectOf2 />
  <componentOf />
</ProcedureEvent>
```


Figure 7. The final output of data and service mapping process, to transfer flu-shot data of a patient.

7. System architecture and implementation

A major goal of this case study is to offer a pilot project on integration of healthcare systems according to the leading-edge standards. It is ideal to provide general development steps for the proposed framework such that the procedures and results can be reused by other developers in similar projects. In order to achieve this generality, we decided to use available industrial products and show how they can be adopted in major projects while complying with healthcare standards. This decision is necessary to prevent the proprietary implementations to generate vendor/application dependency and less usability.

Oracle HTB development environment
Oracle's Healthcare Transaction Base (HTB) is a Service Oriented Architecture (SOA) that supports the integration, development, and operation of a full spectrum of healthcare applications. The rational behind choosing HTB as implementation environment is that HTB follows HL7 v3 messaging standards and is compatible with Infoway infostructure which are two major goals in this project. The list of HTB services [25] which are used in this project are as follows.

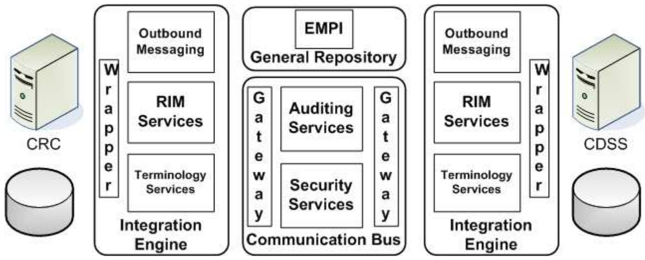

Figure 8. Integration architecture.

Enterprise Master Person Index Services (EMPI): these services provide interfaces that include duplicate identification prevention and management, as well as linking functionality to the related person records. This service is necessary to fetch patient, care givers and other involved people information from distributed registries.

Messaging Services: these services are based on HL7 v3 messaging standard and are central to the integration of data from disparate third-party systems. The XML schemas and transactions which are resulted from the refinement process explained in previous section are given to outbound message processor to generate the HL7 v3 XML messages.

Enterprise Terminology Services (ETS): which provides tools for managing the competing and overlapping standard terminologies and their associated complexities to achieve interoperability. The solution supports the definition of cross-mappings between terminologies. This service is used to map the local system terms with the standards terms from different standard terminologies.

Security Services: HTB relies on *responsibility based* access, single sign-on, authentication and authorization features, consent management, audit trail as well as data encryption.

System architecture

Figure 8 illustrates the integration of the two legacy systems with Infoway's standard distributed architecture. It is composed of two integration engines, a communication bus, and general registries. The integration engine reside between legacy systems and communication bus. It contains a wrapper and three components from HTB such as ETS, RIM services, and messaging services, where the latter includes *outbound* message processor for sender and *inbound* message processor for receiver. The wrappers perform the mappings mentioned in Section 3.1, and interact with the above HTB services within the integration engine to generate the HL7 v3 messages.

The communication bus securely transfers the messages from source to destination, based on the information found in the header of the messages. The communication bus uses gateways form HTB which is responsible for using web service framework to transfer data. *Security* and *Auditing* services from HTB are used to apply the security rules. General registries are also used in the process of message creation. Finally, the EMPI service of HTB is used to retrieve information about people.

A typical scenario

A typical scenario in our case study follows. CRC sends the profile of a patient to C3VT to get the recommendations or guidelines that are related to the profile. The components of the above architecture are called in the following manner to complete this scenario. The global registry section (EMPI service) is called to find the patient's profile in the database. The wrapper inside the integration engine converts the parameters generated by EMPI to CRC database parameters. The wrapper selects the required transaction and data fields and uses RIM services to create different entities such as organizations, people and requests that compose the “message payload”. HTB outbound message processor generates sender, receiver and trigger events which compose the ”message wrappers”. Once the message is generated, it is passed to communication bus to send the message and receive the acknowledgment. Before sending the message, the security service is used to authenticate and authorize the person for the requested action. Gateway service performs this task based on the information of message wrappers. The auditing block records all the events within the communication bus. At the integration engine of the receiver site, HTB inbound message processor parses the received message into ingredients and checks for the consistency of the received message. RIM services are used to traverse the query response graph in order to retrieve the required data (in our case, the recommendations or warnings).

8. Discussion and Conclusion

Traditional healthcare information systems require fundamental re-engineering to interoperate with new network-centric environments. Standards organizations such as HL7 and Canada Health Infoway have provided the ground for these systems to manage domain information in a way that different participants can integrate their proprietary legacy information systems to a nation-wide network and use widely approved services to communicate with a large group of clients. The same standardization philosophy can be provided for different purposes and domains, such as: security and defence (army), business and trading (e-business, e-commerce), organization systems (e-government), financial systems (banking and trading). These systems can be categorized as very large systems or systems of systems. The main characteristic of these largely distributed systems is being *Network Centric* which refers to widely usage of network based applications and data communication using different web-based architectures. Such systems, usually use providers or technologies which restrict the widely usage of their internal services by their local community. In this respect, the new standards in healthcare domain provide advanced techniques that allow data and service identification and interoperability to be performed in a very systematic manner. This allows the common reverse engineering task "data and service migration" to be accomplished with little help from the healthcare experts. This is a major advance in smoothing the task on interoperation of legacy systems. Furthermore, national standardization organization (Canada Health Infoway) has standardized a network-centric distributed infrastructure (namely *infostructure*) that allows standard-based legacy systems to be connected to each other from different provinces of Canada to view, update, and operate on patients' clinical data from everywhere at anytime, and only by authenticated individuals.

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